NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3365

AN ANALYSIS OF ACCELERATIONS, AIRSPEEDS, AND GUST VELOCITIES FROM THREE COMMERCIAL OPERATIONS OF ONE TYPE OF MEDIUM-ALTITUDE TRANSPORT AIRPLANE

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AN ANALYSIS OF ACCELERATIONS, AIRSPEEDS, AND GUST VELOCITIES FROM THREE COMMERCIAL OPERATIONS OF ONE TYPE OF MEDIUM-ALTITUDE TRANSPORT AIRPLANE

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SUMMARY

Time-history data obtained by the NACA VGH recorder from one model of a four-engine civil transport airplane during operations on three routes are analyzed to determine the magnitude and frequency of occurrence of gust velocities, gust and maneuver accelerations, and the associated airspeeds. Variations of the gusts and gust accelerations with route and flight condition are indicated. Estimates of the overall gust and gust-load histories for extended operations on one route are obtained by supplementing the data from the NACA VGH recorder with available data from the NACA V-G recorder.

INTRODUCTION

Past analyses of data from the NACA V-G and the NACA VGH recorders (see, for example, refs. 1 and 2) have yielded information on the magnitude and frequency of occurrence of gust velocities, gust and maneuver accelerations, and the associated airspeeds and altitudes for several types of airplanes flown by different operators on various routes. This information in the past has proved useful in the formulation of design requirements, in studies of fatigue problems, and in the prediction of gust and load histories for new types of operations.

As a continuation of the study of the gust and load histories for transport airplanes, three samples of VGH records have been obtained from four-engine commercial transport airplanes. These samples represent 1,012, 1,958, and 1,080 flight hours of operation on a transcontinental, trans-pacific, and transatlantic route, respectively, and cover operations up to an altitude of approximately 25,000 feet. A sample of V-G data covering about 15,000 hours also has been obtained from the transcontinental operations.

The VGH data have been analyzed to determine the magnitude and frequency of occurrence of gust velocities, gust and maneuver accelerations, and the associated airspeeds for each of the three operations. The V-G data are used to supplement the VGH data from the transcontinental operation in order to derive estimates of the overall gust and gust acceleration histories for this operation. In addition, the V-G data have been used to indicate the frequency of attaining high values of indicated airspeed.

INSTRUMENTATION AND AIRPLANE

The data were collected with NACA VGH and V-G recorders which are described in detail in references 3 and 4, respectively. The NACA VGH recorder yields a time-history type of record of indicated airspeed, altitude, and normal acceleration from which the detailed load and gust history of the airplane, together with pertinent operating conditions such as airspeeds and altitudes, can be obtained. The record from the NACA V-G recorder represents the maximum accelerations which occur throughout the airspeed range for the period covered by the record, usually 100 to 250 flight hours. The V-G data are used, therefore, primarily to obtain estimates of the maximum and relatively infrequent gust velocities, accelerations, and airspeeds, whereas the VGH data are used for detailed studies of gust and load histories. A more complete discussion of the nature and uses of the data from the two recorders is given in reference 2.

Characteristics of the airplane which are pertinent to the evaluation of the data are described in the following table:

Design gross weight, W, lb	147,000
Wing area, S, sq ft	1,720
Aspect ratio, A	11.70
Mean aerodynamic chord, $\bar{c}$, ft	12.88
Slope of lift curve per radian (computed), m	5.12
Design speed for maximum gust intensity (indicated), V_B, mph	202
Design cruising speed (indicated), V_C, mph	312
Never-exceed speed (indicated), V_{NE}, mph	390
Limit-gust-load factor (computed)	2.18
Gust alleviation factor for gross weight (ref. 5), K	1.21

The values listed in the table were obtained from the airplane design manual unless otherwise indicated. The slope of the lift curve was calculated (as recommended in ref. 6) from the relation $\frac{6A}{A + 2}$, where

A is the aspect ratio. The limit-gust-load factor of 2.18 was computed according to current Civil Air Regulations (ref. 5). This value is based on a gross weight of 147,000 pounds and an effective gust velocity U_e of 30K feet per second at the design cruising speed V_C of 312 miles per hour (ref. 6). Although the limit-gust-load factor was calculated to be 2.18, the airplane was designed to the minimum maneuver load factor of 2.5 as required by the regulations (ref. 5).

SCOPE OF DATA

The VGH data were obtained from three airplanes flown on different routes by three operators. The operations covered by the data and the sample size from each operation are summarized in the following table:

	Operation A	Operation B	Operation C
	New York to Europe and South America	Los Angeles to Honolulu to San Francisco	Northern transcontinental
Average length of flight, hr	4.63	8.4	2.03
Average operating altitude, ft	12,700	12,400	13,500
Average indicated airspeed, mph	213	208	218
Total hours of record available	1079.8	1958.6	1012.5
Dates of record collection	Mar. 1952 to Sept. 1953	Nov. 1951 to Dec. 1953	Feb. 1950 to May 1952

As shown in the table, the main differences among the three operations are the routes flown and the average length of flight.

The V-G data were obtained from four airplanes used in operation C and covered 15,387 hours of flight during the period from January 1951 to July 1953.

EVALUATION OF RECORDS

VGH Records

The VGH records from each operation were evaluated essentially in accordance with the methods used in references 2 and 7 to obtain frequency distributions of gust and maneuver accelerations, airspeeds, and altitudes. For these evaluations, each flight on the VGH records was divided into three flight conditions - climb, en route, and descent. The climb condition covered the time from take-off until the airplane began to maintain level flight as was indicated by the altitude trace of the record. The descent was considered to begin when the airplane began to lose altitude consistently and to end when the airplane touched down. The portion of the flight between the climb and descent was considered to be the en-route condition and ordinarily contained some en-route changes in altitude.

In order to distinguish between maneuver and gust accelerations in the records, the criterion used was that gust accelerations have a much higher frequency than maneuver accelerations and that the positive and negative gust accelerations in the VGH records follow one another in a random manner. In addition, high-frequency low-intensity fluctuations of the airspeed trace occurred simultaneously with the gust accelerations but were not apparent during maneuvers.

The evaluation procedure consisted of reading from the records the gust and maneuver accelerations by using the steady-flight position of the acceleration trace as a reference. The threshold values from which the accelerations were read differed and this difference depended upon whether the acceleration resulted from a maneuver or from a gust. Only the maximum value was read for each deflection of the acceleration trace greater than the given threshold value. Each gust acceleration which exceeded a threshold of ±0.3g was read and tabulated, together with the corresponding airspeed and altitude values. Inasmuch as the maneuver accelerations were smaller in general than the gust accelerations, a reading threshold of ±0.1g was used in evaluating maneuver accelerations. The maneuver accelerations were also classed and tabulated, as in reference 7, according to the purpose of the flight. Thus, maneuver accelerations which occurred during routine operational flights are classed as "operational maneuvers" and those which occurred during airplane or pilot check flights are called "check flight" maneuvers. For operation C, the check-flight-maneuver data were taken from reference 7 where the distribution was given to a threshold of ±0.3g under the listing of airplane E.

The evaluation of the records to obtain distributions of airspeed and altitude consisted simply of tabulating the indicated airspeed and pressure altitude for each 1-minute interval of flight. The number of flight hours evaluated to obtain the various distributions of acceleration, airspeed, and altitude are indicated in the following table:

	Operation A	Operation B	Operation C
Total record hours available	1079.8	1958.6	1012.5
Hours evaluated for gust accelerations, airspeeds, and altitudes	1078.5	1953.4	875.5
Hours evaluated for check-flight maneuvers	1079.8	1958.6	1012.5
Hours actually spent in check flights	1.3	5.2	7.5
Hours evaluated for operational maneuvers	306.8	309.6	252.3

As shown in the table, most of the available records were evaluated for airspeed, altitude, gust, and check-flight-maneuver acceleration data. About 137 hours of records for operation C were not evaluated for gust accelerations because of the poor quality of the record. It may be noted that the amount of time actually spent in check flights was small and varied from 1.3 to 7.5 hours. Previous work (ref. 7) has indicated that reasonably accurate estimates of the frequency of operational maneuvers may be obtained from record samples as small as about 60 hours. In order to reduce the evaluation time, therefore, only portions of each sample of a record were evaluated for operational maneuvers.

Gust velocities were derived from the gust accelerations and the associated airspeeds and altitudes by means of the gust equation discussed in reference 8:

$$U_{de} = \frac{2Wa_n}{K_g \rho_o V_e m S}$$

where

U_{de} derived gust velocity, fps

W airplane weight, lb

a_n normal acceleration, g units (corresponds to Δn used in ref. 8)

K_g gust factor

ρ_o air density at sea level, slugs/cu ft

V_e equivalent airspeed, fps

m slope of lift curve per radian

S wing area, sq ft

The values for the gust factor K_g were based on the mass parameters of the airplane computed for the midpoint altitude of each 5,000-foot interval and varied from 0.750 for 2,500 feet to 0.812 for 22,500 feet. Since detailed information on the operating weight at the time of gust encounters was not available, an assumed average operating weight of 0.85 design weight was used in determining the values of K_g and in calculating the gust velocities. It should be noted that because of the use of the revised gust-load formula the derived gust velocities U_{de} for the present data are higher by a factor of roughly 1.6 than the corresponding effective gust velocities U_e computed in most past analyses of airline gust data (see, for example, ref. 1).

V-G Records

The values read from each V-G record were the maximum positive and negative accelerations $a_{n_{max}}$ occurring at speeds above 140 miles per hour and the maximum indicated airspeed V_{max}. No accelerations were read at speeds below 140 miles per hour in order to exclude impact shocks during landing. The 166 V-G records evaluated represented from 62 to 111 flight hours per record, the average number of hours being 92.6.

The maximum positive and negative gust velocities $U_{de_{max}}$ were computed for each record by using the acceleration values and the respective values of airspeed in the gust-velocity formula previously presented. The value of the gust factor K_g used for evaluating the gust velocities from the V-G data is based on the average operating altitude of 13,500 feet and an assumed average operating weight of 0.85 design weight.

RESULTS

The data evaluated from the VGH and V-G records are given in tables I to IV in the form of frequency distributions of the observed values of acceleration, gust velocity, and airspeed. Class intervals of 0.1g for acceleration, 4 feet per second for gust velocity, and 5 miles per hour for airspeed were used for grouping the data in the distributions.

In order to compare the gust accelerations for the three operations, the data given in table I(a) are plotted in figure 1 in terms of the average number of accelerations greater than given values per mile of flight. For this purpose, the positive and negative distributions of a_n were combined without regard to sign since the two distributions were essentially symmetrical. The ordinate values were obtained by progressively summing (by starting with the frequency for the largest acceleration) each combined frequency distribution Σf and then dividing each sum by the flight distance l represented by the data.

The frequency of occurrence of gust accelerations by flight condition (climb, en route, and descent) for each of the three operations is given in figure 2. The data plotted in the figure were obtained from table I(b).

The positive and negative distributions of accelerations from operational and check-flight maneuvers (table II) are plotted in figure 3 for each operation in terms of the frequency of occurrence of accelerations greater than given values. In order to compare the magnitude and frequency of occurrence of accelerations caused by gusts and maneuvers, the gust-acceleration data of figure 1 and the combined distributions of check-flight- and operational-maneuver data are plotted in figure 4 for each operation. The combined maneuver distributions for each operation were obtained by summing the ordinate values of the operational- and check-flight-maneuver distributions in figure 3.

The synthesis of V-G and VGH data permits an estimate to be made of the overall gust-load history for a given operation (see ref. 2). Owing to the envelope nature of the V-G records, the V-G data provide information on only the largest accelerations experienced. From the VGH data, on the other hand, reliable estimates of all the smaller values are possible provided representative samples of data are used. The V-G and VGH acceleration data for operation C are plotted in figure 5. In figure 5, a curve has been faired through the data points to indicate the expected frequency of occurrence for the entire range of accelerations for the operation.

In order to compare the gust velocities encountered in operations A, B, and C, the gust data from table III(a) are plotted in figure 6 in terms of the frequency of occurrence of gust velocities greater than given values per mile of flight. The gust distribution for operation C is also plotted in figure 7 together with the distribution of maximum gust velocities $U_{de_{max}}$ (table III(b)) obtained from the V-G data for the operation. The solid line in figure 7 was faired to represent the overall gust history for the operation.

The distributions of indicated airspeed obtained from the 1-minute tabulations of the VGH data are given in figure 8 as the portion of the total time in each flight condition which was spent at given airspeeds. In order to compare these data with the airspeeds used in rough air, the distributions of airspeed at which gust accelerations greater than ±0.3g were experienced are shown in figure 8 as dashed curves. The design speed for maximum gust intensity V_B and the design cruising speed V_C are also indicated in figure 8.

The distribution of maximum airspeeds V_{max} (table IV) obtained from the V-G data for operation C is plotted in figure 9 in terms of the average number of flight miles to exceed a given value of airspeed.

PRECISION AND RELIABILITY OF RESULTS

The accuracy of the data presented herein depends on the inherent instrument errors, installation errors, and reading errors. The inherent instrument errors of the VGH recorder and a general discussion of installation errors for the instrument are given in reference 3. A discussion of reading errors applicable to the present VGH data is contained in reference 2. The VGH installations met the basic installation requirements given in reference 3; consequently, it is felt that the installation errors for the present data are negligible. The estimated total error in the VGH data for each of the quantities measured is:

Acceleration, g	±0.05
Indicated airspeed, mph	
At 100 mph	±5
At 250 mph	±2.5
Pressure altitude, ft	
At 2,000 ft	±150
At 20,000 ft	±300

On the basis of laboratory calibrations (ref. 4) the errors inherent in the NACA V-G recorder are less than ±0.1g for acceleration and about 3 miles per hour for airspeed. Errors which may have occurred in reading the V-G records are believed to be negligible.

In addition to the problem of instrument precision, there is also a problem regarding the statistical reliability of the data samples (that is, applicability to extended periods of operation). Unfortunately, precise methods of determining the statistical reliability of the present results are not available. An indication of the reliability of the results may be obtained, however, by examining the variations among the data from individual records and groups of records forming the total sample. Based on such observations and on past experience with results of the type presented, it is estimated that the total distributions of gust accelerations (fig. 1) and gust velocities (fig. 6) are reliable within a factor of about 2 (on the ordinate scale) at the smaller values and a factor of 3 at the higher values. These factors represent spreads of roughly 10 percent in the gust accelerations of figure 1 and the gust velocities of figure 6. The reliability of the distributions by flight condition is less, however, since these distributions represent smaller data samples. The distributions of accelerations, gust velocities, and airspeeds obtained from the V-G data are estimated to be reliable within a factor of 4 for the higher values.

A discussion of the reliability of maneuver acceleration distributions obtained from operational data is given in reference 7 which indicated that maneuver distributions were changed only slightly by increasing the sample size from 60 to 300 hours. Based on the information in reference 7 and on comparisons of data samples of different sizes, the distributions of maneuver accelerations given in figure 4 are estimated to be reliable within a factor of about 3 over the range of the data. It should be noted that higher values of maneuver accelerations may occur in extended operations. The manner in which the maneuver distributions should be extrapolated for extended operations, however, is not known.

DISCUSSION

Gust Accelerations

Comparison of the curves of figure 1 indicates that, for the three operations shown, differences of about 3:1 are apparent in the frequencies of occurrence for given values of acceleration. For a given frequency of occurrence, for example, 10^{-4} per mile, figure 1 indicates that the accelerations for operations A and C are approximately 15 percent higher than those for operation B. Differences of the order of 3:1 in these data may be sufficiently large as to be of importance to the operator and designer in considering such factors as fatigue life. Whether these differences are real or are due to sampling fluctuations unfortunately is not known because presently available statistical techniques do not provide an answer to this question in a simple manner.

Inspection of figure 2 indicates that, for each of the three operations, the greatest number of gust accelerations per mile of flight were experienced in the descent condition and the least number in the en-route condition. The higher frequency of accelerations during the descent condition is due to the combined effects of increased gust frequency at low altitudes and high indicated airspeeds during the descent. From table I(b) it may be seen that a high percentage (about 40 to 75 percent) of the total number of accelerations for each operation occurred during descent. A reduction in airspeed for this portion of flight could result, therefore, in a substantial reduction in the total number of accelerations.

Calculations indicate, for example, that a 10-percent reduction in airspeed during descent for operation B would result in a reduction of about 30 percent in the total number of accelerations greater than 0.3g.

Maneuver Accelerations

Figure 3(a) indicates that the distributions of accelerations caused by operational maneuvers are similar for the three operations and that differences of about 3:1 exist in the frequencies for given acceleration values. Also, the distributions of positive and negative accelerations for each operation are essentially symmetrical. A breakdown of the operational-maneuver data by flight condition showed that the descent condition had the highest frequency of occurrence per mile of flight and the climb condition the next highest. A comparison of the present frequency distributions with the distributions given in reference 7 for five operations involving transport airplanes indicates good agreement with respect to the symmetry of the positive and negative values. The frequency distributions for the present operations lie at the lower limit of the distributions shown in reference 7 and, from the overall viewpoint, do not appear to be significantly different.

Figure 3(b) shows that the magnitude and frequency of occurrence of positive and negative check-flight accelerations are significantly higher for operation C than for the other two operations. In addition, the data show that, for each operation, the magnitude and frequency of the positive accelerations are higher than those for the negative values. Although a larger percentage of the total flight time of operation C was spent in check flights than for operations A and B, this fact accounts for only a part of the large difference noted between the frequencies of accelerations. The remainder of the difference is due to differences between airline and pilot practice in regard to the type, severity, and frequency of maneuvers performed during check flights. The applicability of the results in figure 3(b) to extended periods of operation may be open to some question owing to the small number of check-flight hours for which data were available (table II(b)).

Figure 4 shows that the magnitude and frequency of occurrence of accelerations caused by gusts are higher than those caused by maneuvers (operational and check-flight) for operations A and B. For operation C, however, the maneuver accelerations occur more frequently than gust accelerations for values of a_n greater than 0.4g. It appears, therefore, that the relative contribution of gusts and maneuvers to the total number of loads varied between operators and is determined largely by airline practice in regard to the performance of check flights.

Inspection of figure 5, which gives an estimate of the overall gust load history for operation C, indicates that the frequency of occurrence per mile of flight decreases from about 4×10^{-3} for a_n of 0.3g to 3×10^{-6} for a_n of 1.0g. The frequency of occurrence of accelerations greater than 1.18g, which corresponds to the limit-gust-load-factor increment, is about 8×10^{-7} per mile or once in approximately 1.3×10^{6} flight miles. This frequency of exceeding the acceleration corresponding to the limit-gust-load-factor increment is in good agreement with the results reported in reference 9 for seven other operations involving both twin-engine and four-engine transports. Figure 4 indicates that transport airplanes may be subjected at times to large maneuver accelerations, and the possibility exists that V-G data (such as those used in fig. 5) might be biased by maneuvers. Although attempts are made during the evaluation of the V-G records to eliminate obvious maneuver accelerations, particularly those which occur at the lower airspeeds during descent and landing, some bias might unknowingly be present in the results shown.

Gust Velocities

Figure 6 shows that differences of the order of 2:1 exist among the frequency of occurrence of gust velocities between approximately 15 and 35 feet per second for the three operations. The gust distributions in figure 6 are incomplete for gust velocities below about 15 feet per second because of the method of evaluation (see ref. 2) and the reliability of the distributions above about 35 feet per second is decreased because of the small number of observed values. Over the reliable range (15 to 35 feet per second) of the data, however, the results in figure 6 indicate that the differences in the frequency of occurrence of gust velocities on the three routes would result in a 2:1 variation in accelerations for the three operations if the airspeed practices were similar.

In order to determine possible effects of flight altitude on the gusts encountered, the gust-velocity data from the VGH records were analyzed to determine the variation of the gust frequency with altitude. The results of the analysis showed a large decrease in the number of gusts per mile of flight with increasing altitude for each of the three operations. As an example, gust velocities of given intensities were encountered only about one-tenth as frequently above 10,000 feet as below this altitude.

The estimated overall gust history for operation C given in figure 7 shows, as would be expected, a continuous decrease in the frequency of occurrence for increasing values of gust velocity. For example, figure 7 indicates that the frequency of occurrence of U_{de} equal to or greater than 40 feet per second is only about one-fiftieth that for U_{de} of 20 feet per second. Figure 7 shows that a gust velocity of 50 feet per second is exceeded, on the average, 5×10^{-6} times per mile or once in approximately 2×10^{5} flight miles. This frequency of exceeding U_{de}

of 50 feet per second agrees with the results given in reference 9 for seven other operations involving both twin-engine and four-engine airplanes. As previously noted, maneuvers might have biased the V-G acceleration data and, accordingly, the gust velocities given in figure 7 which were derived from the same data would also be biased.

Airspeeds

The overall speed distributions given in figure 8 (solid lines) indicate that, for each operation, the indicated airspeeds in climb were lower than those for the en-route condition and that the highest airspeeds occurred during the descent. Comparison of the distributions for the climb conditions shows that differences of 10 to 15 miles per hour exist among average climb speeds for the three operations. Similar differences are evident among the airspeeds for en route and descent and evidently result from differences among the operating practices of the operators. Each of the three airplanes were normally operated well below the design cruising speed V_C of 312 mph, the average speeds being $0.68V_C$, $0.67V_C$, and $0.70V_C$ for operations A, B, and C, respectively.

Inspection of figure 8 indicates that, for each of the three operations, the airspeed distributions in rough air are very similar to the airspeed distributions for the overall operations. Thus, there appears to have been little or no reduction in airspeed upon encountering rough air. For the climb and en-route conditions, figure 8 indicates that the average speeds were close to the design speed for maximum gust intensity V_B of 202 miles per hour and, consequently, no general reduction in airspeed was required upon encountering rough air. The lack of a reduction in airspeed in rough air for the descent condition may be due to the fact that the pilot did not anticipate the turbulence in time to reduce the airspeed or to a practice of not reducing airspeed unless very severe turbulence is encountered.

The distribution of maximum airspeeds given in figure 9 for operation C shows that the maximum airspeed recorded in the 15,000 hours of data was about 340 miles per hour. The trend of the airspeed distribution suggests that the possibility of the never-exceed speed V_{NE} of 390 miles per hour being exceeded is very remote. For operations involving other types of four-engine airplanes, reference 9 indicates that the distance to exceed V_{NE} varied from 0.1×10^6 to 20×10^6 flight miles. In comparison with those operations, therefore, the frequency of exceeding V_{NE} for operation C is significantly lower.

CONCLUDING REMARKS

An analysis of VGH data obtained on a four-engine transport airplane operated on three commercial routes indicates differences of about 3:1 between the acceleration distributions and about 2:1 between the gust-velocity distributions for the three different operations. The relative contribution of gusts and maneuvers to the total number of loads varied between operators and is determined largely by airline practice in regard to the performance of check flights. The airspeed practices for the three operations were similar for flight in both smooth and rough air. Estimates of the frequency of experiencing large accelerations and gust velocities are in good agreement with results from similar operations sampled previously.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 8, 1954.

REFERENCES

1. Walker, Walter G., and Steiner, Roy: Summary of Acceleration and Airspeed Data From Commercial Transport Airplanes During the Period From 1933 to 1945. NACA TN 2625, 1952.

2. Press, Harry, and McDougal, Robert L.: The Gust and Gust-Load Experience of a Twin-Engine Low-Altitude Transport Airplane in Operation on a Northern Transcontinental Route. NACA TN 2663, 1952.

3. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

4. Taback, Israel: The NACA Oil-Damped V-G Recorder. NACA TN 2194, 1950.

5. Anon.: Airplane Airworthiness - Transport Categories. Pt. 4b of Civil Air Regulations, Civil Aero. Board, U. S. Dept. Commerce, Dec. 31, 1953.

6. Donely, Philip: Summary of Information Relating to Gust Loads on Airplanes. NACA Rep. 997, 1950. (Supersedes NACA TN 1976.)

7. Coleman, Thomas L., and Copp, Martin R.: Maneuver Accelerations Experienced by Five Types of Commercial Transport Airplanes During Routine Operations. NACA TN 3086, 1954.

8. Pratt, Kermit G.: A Revised Formula for the Calculation of Gust Loads. NACA TN 2964, 1953.

9. Walker, Walter G.: Gust Loads and Operating Airspeeds of One Type of Four-Engine Transport Airplane on Three Routes From 1949 to 1953. NACA TN 3051, 1953.

TABLE I

FREQUENCY DISTRIBUTIONS OF GUST ACCELERATIONS

(a) Positive and negative accelerations for total VGH samples

Acceleration, a_n, g units	Frequency distribution for -		
	Operation A	Operation B	Operation C
1.1 to 1.2	---	---	---
1.0 to 1.1	---	---	---
.9 to 1.0	---	1	---
.8 to .9	---	---	---
.7 to .8	2	---	2
.6 to .7	4	2	2
.5 to .6	16	8	15
.4 to .5	53	45	81
.3 to .4	289	272	364
-.3 to -.4	218	208	367
-.4 to -.5	59	56	57
-.5 to -.6	11	13	11
-.6 to -.7	4	4	7
-.7 to -.8	1	2	3
-.8 to -.9	1	1	---
-.9 to -1.0	---	---	---
-1.0 to -1.1	---	---	---
-1.1 to -1.2	1	---	---
Total	659	612	909
Sample size, hr	1078.5	1953.4	875.5
Flight miles	2.84×10^5	4.88×10^5	2.35×10^5

TABLE I

FREQUENCY DISTRIBUTIONS OF GUST ACCELERATIONS - Continued

(b) Flight condition

Acceleration, a_n (positive and negative), g units	Frequency distribution for -								
	Climb			En route			Descent		
	Operation A	Operation B	Operation C	Operation A	Operation B	Operation C	Operation A	Operation B	Operation C
0.3 to 0.4	85	89	100	200	131	90	222	260	541
.4 to .5	16	19	10	59	34	18	37	48	110
.5 to .6	1	---	2	22	16	3	4	5	21
.6 to .7	---	---	1	6	3	1	2	3	7
.7 to .8	---	---	1	3	1	---	---	1	4
.8 to .9	---	---	---	1	---	---	---	1	---
.9 to 1.0	---	---	---	---	---	---	---	1	---
1.0 to 1.1	---	---	---	---	---	---	---	---	---
1.1 to 1.2	---	---	---	1	---	---	---	---	---
1.2 to 1.3	---	---	---	---	---	---	---	---	---
1.3 to 1.4	---	---	---	---	---	---	---	---	---
Total	102	108	114	292	185	112	265	319	683
Sample size, hr	81.0	82.1	120.6	896.4	1764.0	600.3	101.1	107.3	154.6
Flight miles	1.93×10^4	1.81×10^4	2.65×10^4	2.33×10^5	4.42×10^5	1.66×10^5	2.80×10^4	2.87×10^4	4.29×10^4

TABLE I

FREQUENCY DISTRIBUTION OF GUST ACCELERATIONS - Concluded

(c) Maximum gust accelerations from V-G records for operation C

Maximum acceleration, $a_{n_{max}}$, g units	Frequency distribution
0.3 to 0.4	2
.4 to .5	28
.5 to .6	84
.6 to .7	91
.7 to .8	63
.8 to .9	25
.9 to 1.0	16
1.0 to 1.1	17
1.1 to 1.2	1
1.2 to 1.3	4
1.3 to 1.4	1
Total	332
Sample size, hr	15,387
Flight miles	4.13×10^6

TABLE II

FREQUENCY DISTRIBUTIONS OF MANEUVER ACCELERATIONS

(a) Operational maneuver

Acceleration, a_n, g units	Frequency distribution for -		
	Operation A	Operation B	Operation C
0.6 to 0.7	-----	-----	-----
.5 to .6	-----	-----	2
.4 to .5	1	1	4
.3 to .4	24	7	11
.2 to .3	144	88	190
.1 to .2	1,473	770	1,196
-.1 to -.2	2,248	1,220	1,183
-.2 to -.3	180	86	198
-.3 to -.4	18	11	16
-.4 to -.5	1	-----	2
-.5 to -.6	-----	-----	-----
-.6 to -.7	-----	-----	-----
Total	4,089	2,183	2,802
Sample size, hr	306.8	309.6	252.3
Flight miles	8.08×10^4	7.75×10^4	6.78×10^4

TABLE II

FREQUENCY DISTRIBUTIONS OF MANEUVER ACCELERATIONS - Concluded

(b) Check-flight maneuver

Acceleration, a_n, g units	Frequency distribution for -		
	Operation A	Operation B	Operation C (1)
1.0 to 1.1	---	---	2
.9 to 1.0	---	---	2
.8 to .9	---	---	11
.7 to .8	---	---	9
.6 to .7	---	---	20
.5 to .6	---	1	25
.4 to .5	---	4	39
.3 to .4	3	15	44
.2 to .3	20	38	---
.1 to .2	74	120	---
-.1 to -.2	48	77	---
-.2 to -.3	5	12	---
-.3 to -.4	---	1	8
-.4 to -.5	---	---	4
-.5 to -.6	---	---	2
-.6 to -.7	---	---	2
Total (positive and negative)	150	268	168
Sample size, hr	1079.8	1958.6	1012.5
Time in check flights, hr	1.25	5.2	7.5
Flight miles	2.84×10^5	4.9×10^5	2.72×10^5

[1]Distribution obtained from reference 7.

TABLE III

FREQUENCY DISTRIBUTIONS OF GUST VELOCITIES

(a) VGH samples

Gust velocity, U_{de}, fps	Frequency distribution for -		
	Operation A	Operation B	Operation C
6 to 10	---	---	---
10 to 14	28	4	173
14 to 18	313	254	419
18 to 22	208	211	225
22 to 26	66	105	60
26 to 30	26	27	19
30 to 34	9	6	7
34 to 38	5	3	5
38 to 42	4	1	1
42 to 46	---	---	---
46 to 50	---	1	---
50 to 54	---	---	---
Total	659	612	909
Sample size, hr	1078.5	1953.4	875.5
Flight miles	2.84×10^5	4.88×10^5	2.35×10^5

TABLE III

FREQUENCY DISTRIBUTIONS OF GUST VELOCITIES - Concluded

(b) Maximum gust velocities from V-G records for operation C

Maximum gust velocity, $U_{de_{max}}$, fps	Frequency distribution
16 to 20	3
20 to 24	16
24 to 28	56
28 to 32	73
32 to 36	74
36 to 40	44
40 to 44	25
44 to 48	20
48 to 52	8
52 to 56	4
56 to 60	5
60 to 64	2
64 to 68	1
68 to 72	--
72 to 76	1
Total	332
Sample size, hr	15,387
Flight miles	4.13×10^6

TABLE IV

FREQUENCY DISTRIBUTION OF MAXIMUM INDICATED AIRSPEED

FROM V-G RECORDS FOR OPERATION C

Maximum airspeed, V_{max}, mph	Frequency distribution
285 to 290	3
290 to 295	4
295 to 300	19
300 to 305	19
305 to 310	41
310 to 315	43
315 to 320	14
320 to 325	12
325 to 330	8
330 to 335	1
335 to 340	1
340 to 345	1
Total	166
Sample size, hr	15,387
Flight miles	4.13×10^6

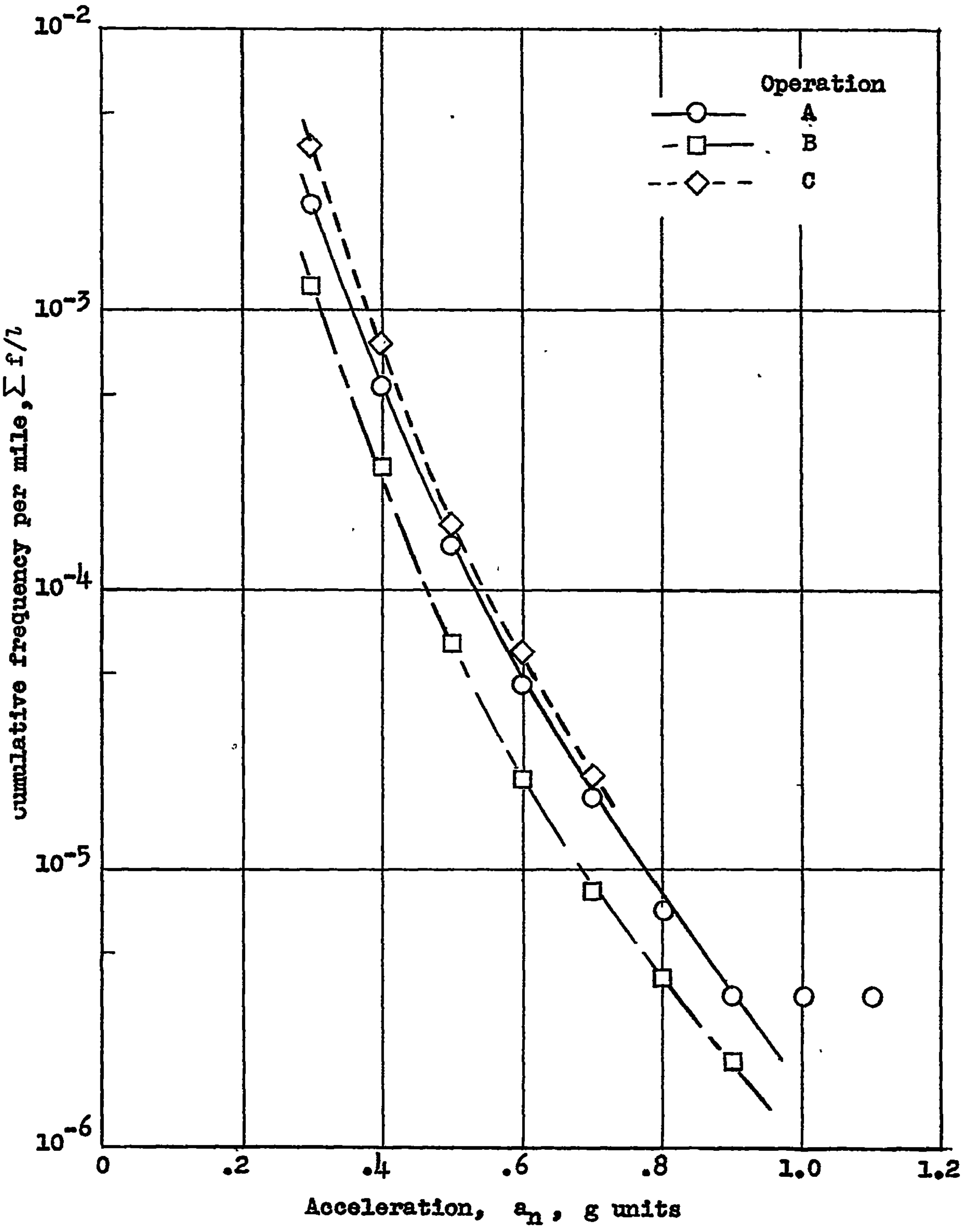
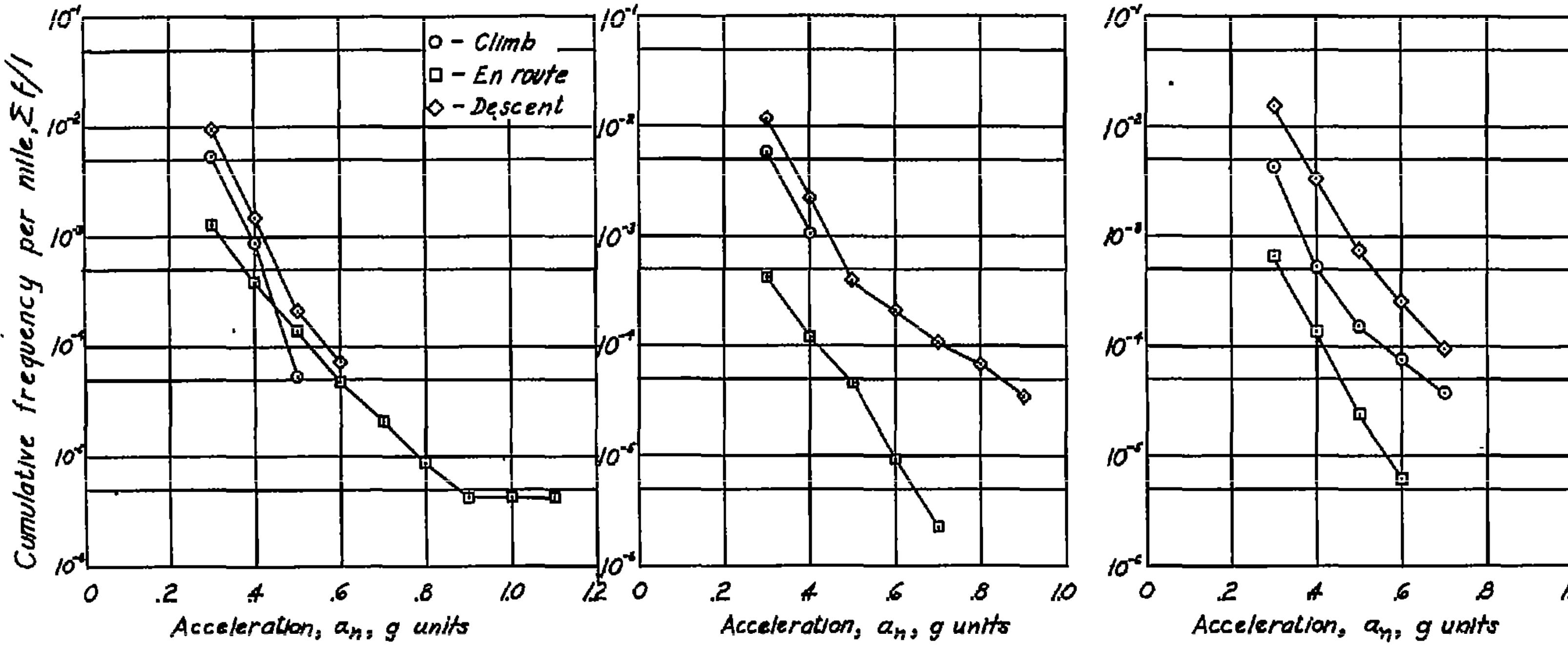


Figure 1.- Comparison of the frequency of occurrence of gust accelerations for three operations.

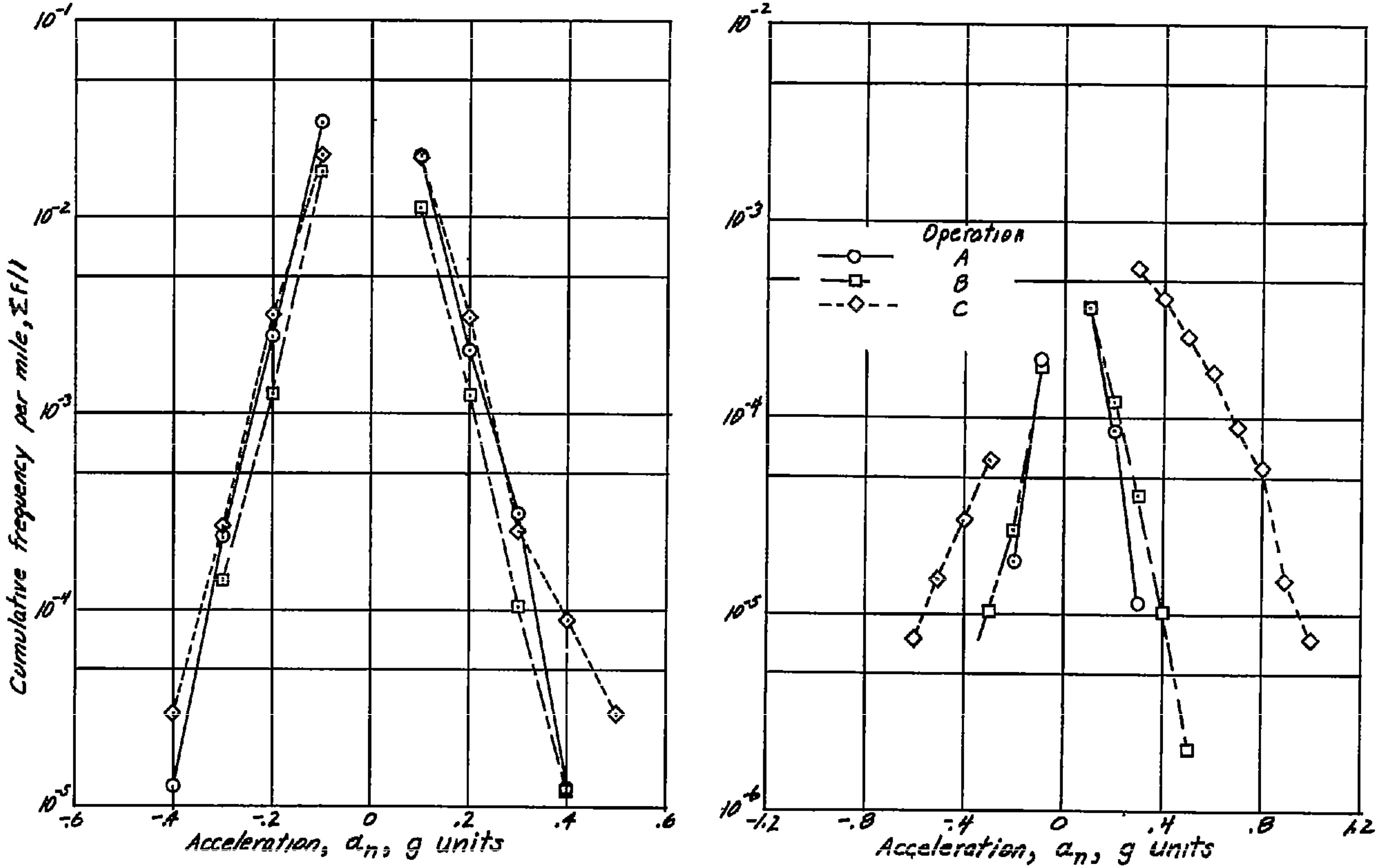


(a) Operation A.

(b) Operation B.

(c) Operation C.

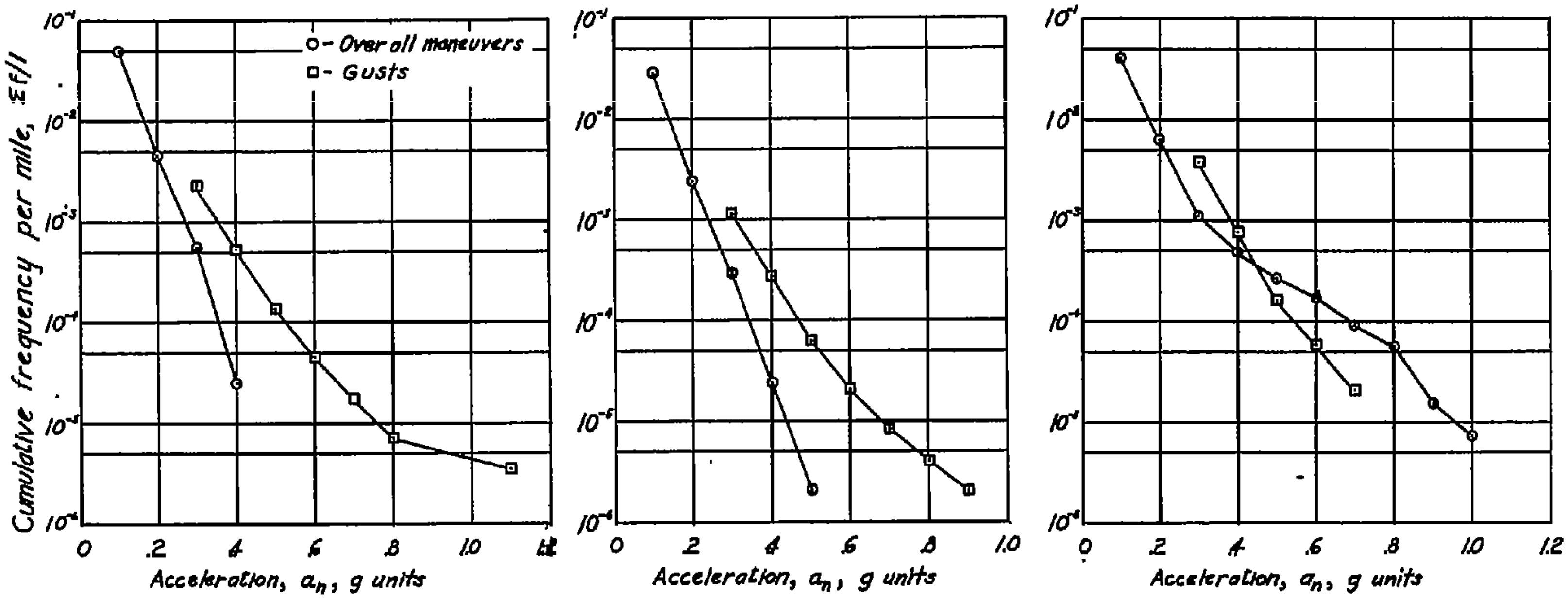
Figure 2.- Comparison of the frequency of occurrence of gust accelerations during climb, en route, and descent for three operations.



(a) Operational maneuvers.

(b) Check-flight maneuvers.

Figure 3.- Comparison of the frequency of occurrence of operational- and check-flight-maneuver accelerations for three operations.



(a) Operation A.　　(b) Operation B.　　(c) Operation C.

Figure 4.- Comparison of the frequency of occurrence of gust and maneuver accelerations for three operations.

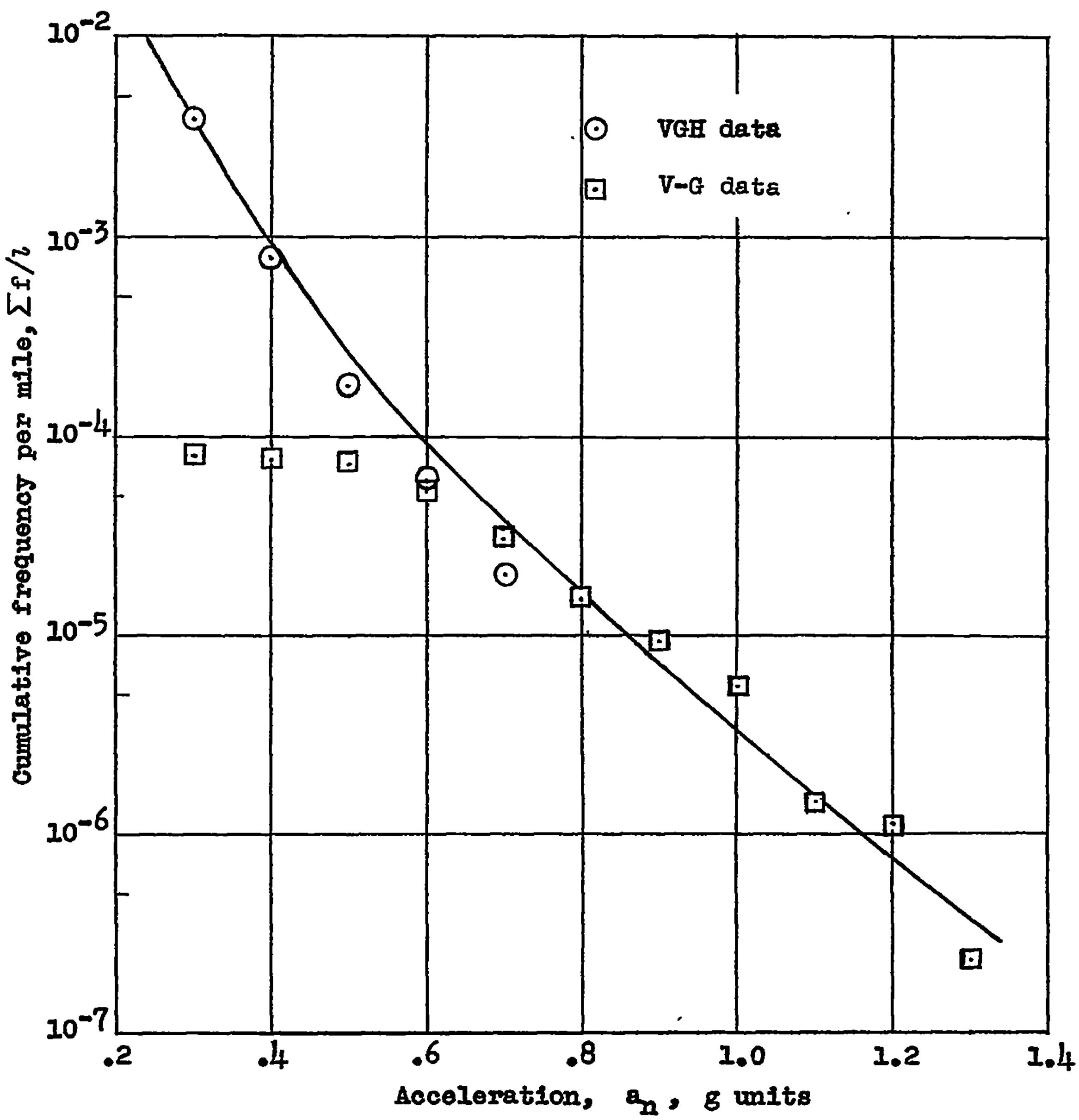


Figure 5.- Composite curve of the frequency of occurrence of gust accelerations for operation C.

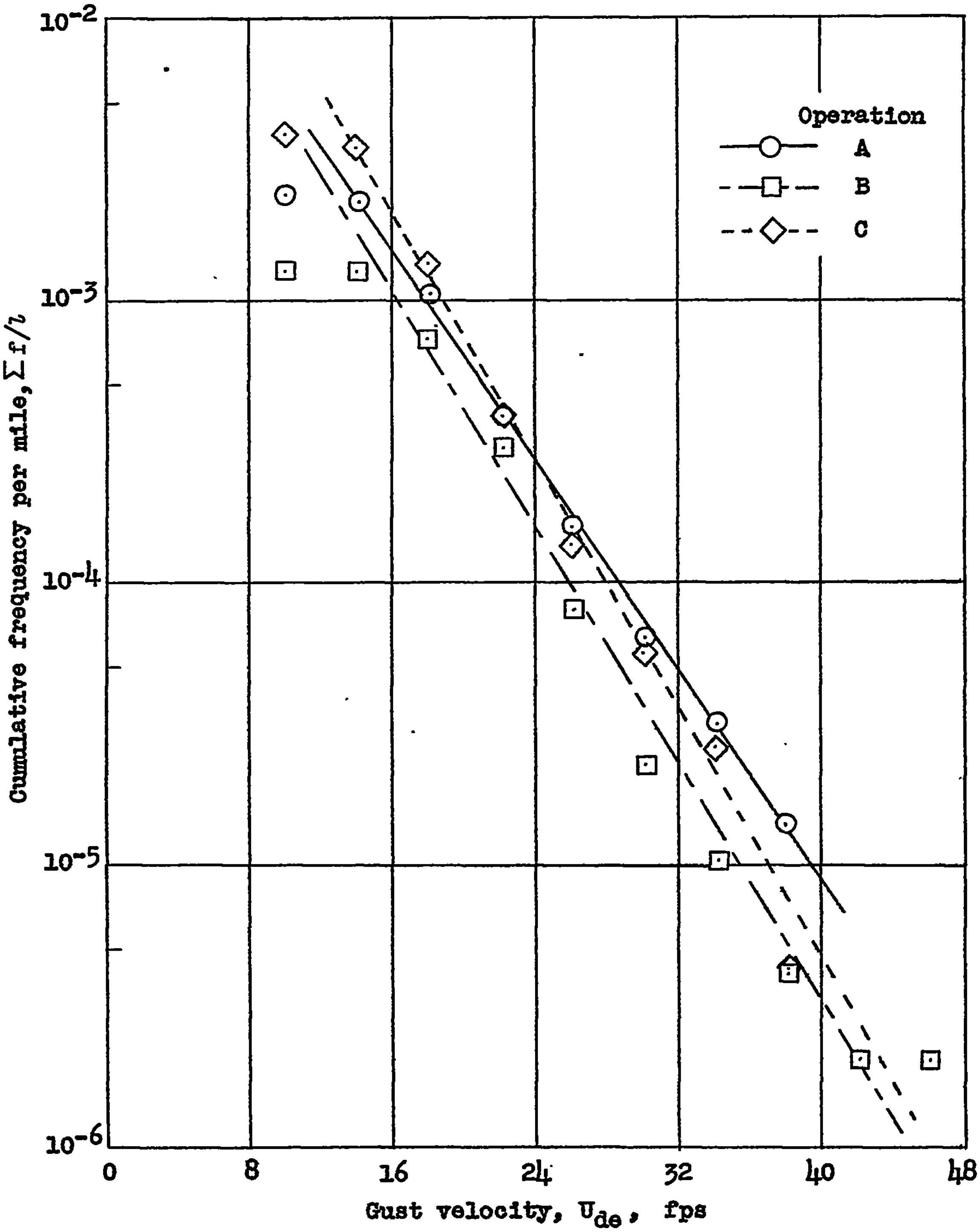


Figure 6.- Comparison of the frequency of occurrence of gust velocities for three operations.

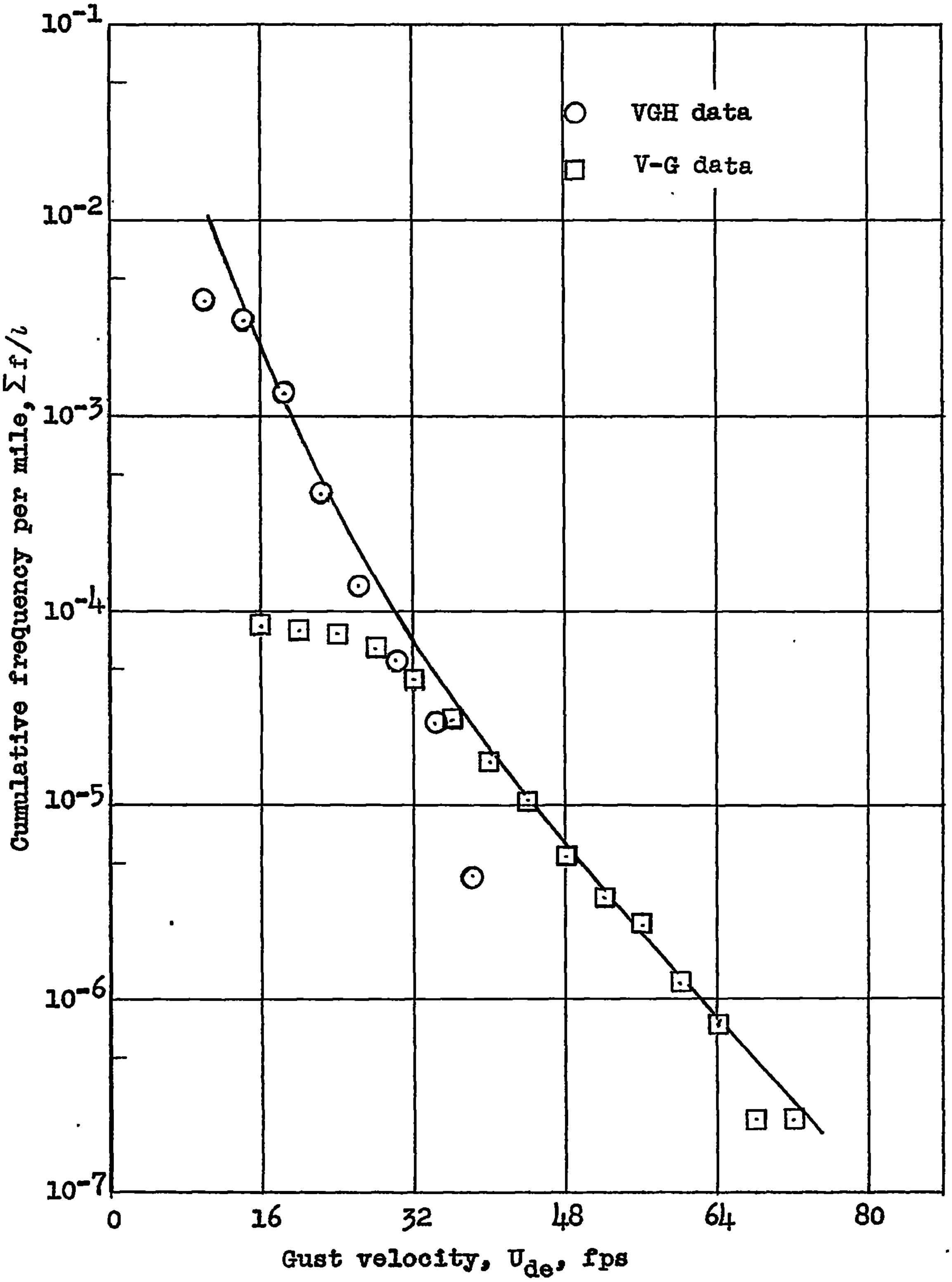
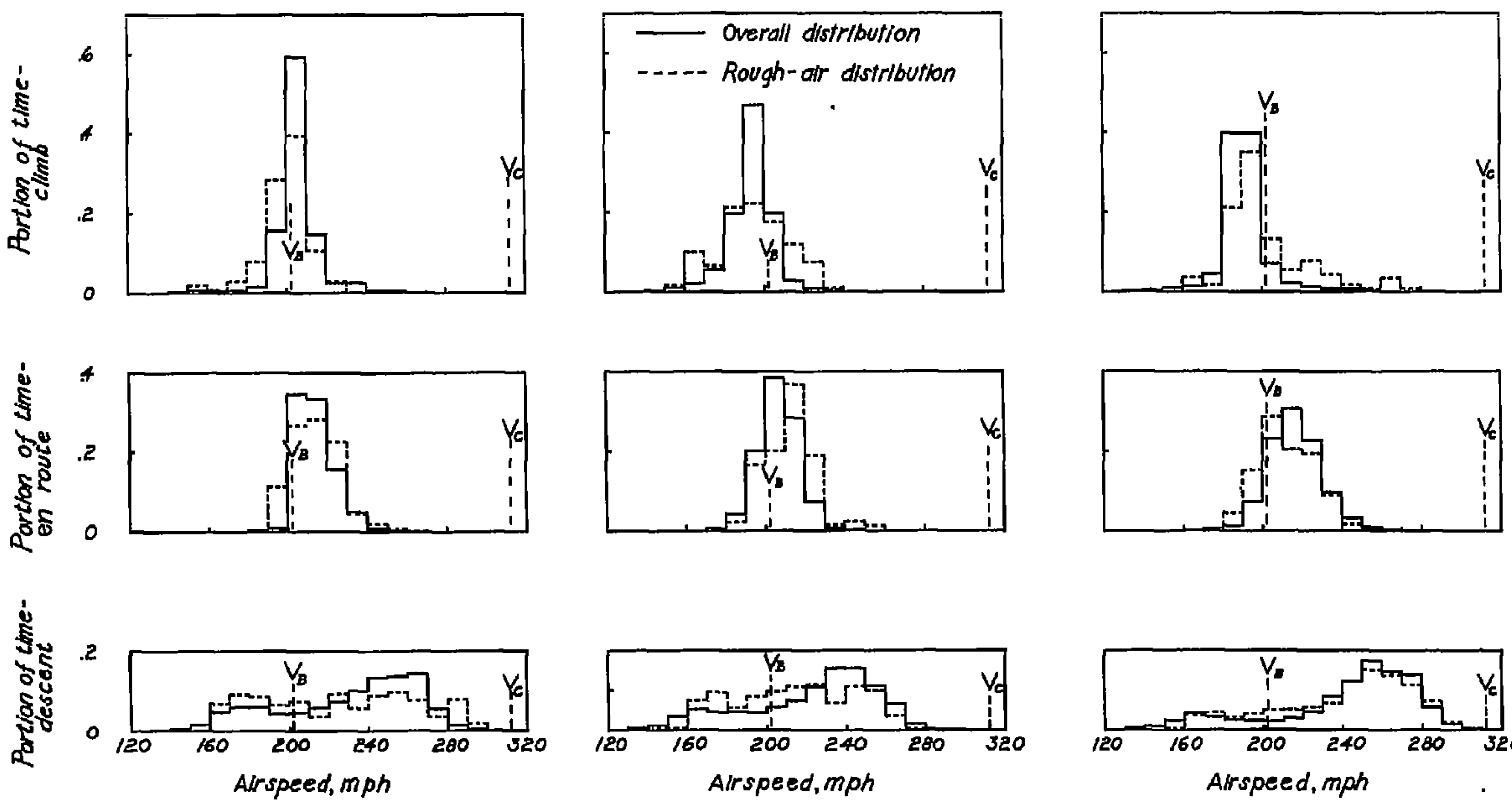


Figure 7.- Composite curve of the frequency of occurrence of gust velocities for operation C.



(a) Operation A. (b) Operation B. (c) Operation C.

Figure 8.- Comparison of distributions of overall airspeed with the distributions of airspeed in rough air by flight condition for three operations.

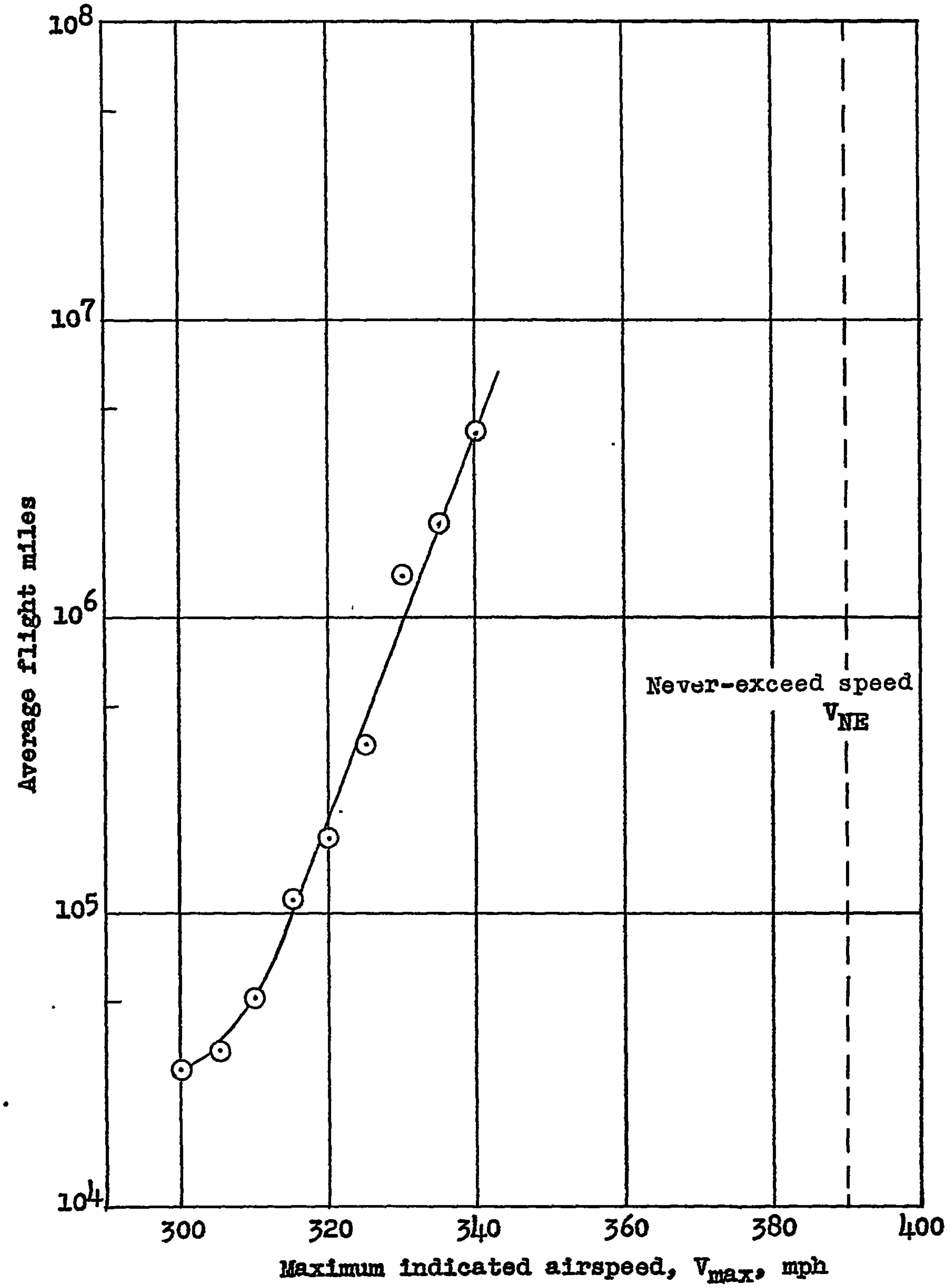


Figure 9.- Average flight miles for the maximum indicated airspeed to exceed a given value. Operation C.

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